RISK MANAGEMENT OF UK MINISTRY OF DEFENCE

EXPLOSIVES STORAGE ACTIVITIES

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INTRODUCTION

1. In 1718 the British Parliament passed an Act on the Keeping of Gunpowder, a measure designed to limit the hazards of accidental explosions. Later, the Explosives Acts of 1875 and 1923 introduced procedures for licensing of explosives factories and storehouses based on such factors as the quantities of explosives involved and the numbers of people exposed to the hazard. Since then, the technical basis for legislation has improved but the goals remain largely unchanged. In the United Kingdom, we seek by prescriptive rules covering the design, construction, management and operation of explosive storehouses to minimise the chance of an explosion occurring. We complement these rules with measures such as quantity-distance (Q-D) standards to ensure that workers, the general public and property and materiel are adequately protected from the effects of an explosion should one occur.

2. Quantity-distance tables, and rules derived from them, are intended to provide an acceptable degree of protection from the potential damaging effects of various types and quantities of explosives. They do not provide absolute safety. This much is clear from the fact that we generally allow smaller separation distances for explosive workers than for other workers who in turn may enjoy a lesser degree of protection than the general public.

3. Within the United Kingdom, standards for military explosives storage including Q-D rules are laid down by the Explosives Storage and Transport Committee (ESTC) of the Ministry of Defence. Similar standards are in place throughout the NATO nations and in many other countries world wide. These standards have the advantage of proven success and they should not be set aside lightly. However, they are not without problems. The ESTC fixed rule based system of regulation assumes that an explosion will occur and is to this extent deterministic and inflexible. Waivers and concession procedures are need to deal with situations outside the normal limits and decisions to grant waivers have to be made with little or no appreciation of the potential consequences. The hazards from sites controlled by Q-D rules cannot readily be compared with the hazards from other sources such as nuclear power plant or chemical storage. Indeed, the hazards from explosives falling in different UN Hazard Divisions cannot be compared. It is difficult therefore in Q-D based regimes to make informed decisions about where to invest resources so as to maximise the benefits of risk reduction.

4. These problems began to be recognised in the United Kingdom Ministry of Defence (MODUK) soon after 1980 and in 1983 work was begun to investigate the possibility of applying quantitative risk assessment (QRA) techniques to the regulation of explosives storage. The idea quickly developed that the risk was made up of two factors; the probability of accidental explosion and the consequences of such an event. These are precisely the factors that the existing fixed rule based system based on prescribed procedures and Q-D standards seeks to control, and within the

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Explosives Storage and Transport Committee the view has taken shape that QRA and fixed rule based systems are different expressions of the same basic principles. They are in effect complementary and not alternatives.

5. While this work was going on, the importance of risk management in ensuring the health and safety of workers began to be more clearly recognised in legislation. In 1989, the Council of the European Communities produced a Directive,[1] the Framework Directive, requiring employers to use risk management techniques. These requirements were implemented in UK law in the Management of Health and Safety at Work Regulations 1992. The process of risk management requires that hazards be identified and the risks of them being realised are assessed. The employer must then act to avoid the risks or to control them. These duties are not absolute; risks are not to be reduced at all costs. Rather, a balance between the benefits of the work activity and the risks associated with it has to be sought. The QRA method developed to deal the storage of explosives by MODUK needs to fit into this legislative framework.

6. The aim of this paper is to describe the QRA system developed by the Explosives Storage and Transport Committee of the United Kingdom Ministry of Defence and give examples of its practical application. It will be argued that QRA should be used with conventional Q-D rule based regulation to achieve efficient and cost-effective management of explosives safety.

DEFINITIONS

7. Terms such as hazard and risk have commonly understood meanings but when used in the context of quantitative risk assessment, these meanings can be ambiguous. Risk in particular could be understood to encompass only the probability of an event such as an explosion actually occurring rather than the broader concept of the probability of a specified harm arising as a consequence. Clear definitions are essential and the terms used in this paper are explained at Annex A.

CONTROL OF SAFETY OF MOD(UK) EXPLOSIVES SITES

8. Before an MOD(UK) explosives facility is allowed to operate it must be licensed. Licences are issued by the Chief Inspector of Explosives for the MOD Service or civilian Department involved against standards which are laid down by the Explosives Storage and Transport Committee (ESTC). For a licence to be issued, the Chief Inspector must be satisfied that in his professional judgement the establishment, when operating within the terms of the licence, will generate risks which are both tolerable and as low as is reasonably practicable. In forming this judgement, the Chief Inspector will take due regard of ESTC advice and Q-D standards and the defence imperative need for the licence. Having issued a licence, the Chief Inspector will carry out periodic inspections to ensure that the licence conditions continue to be met. The licensing and inspection process is itself defined in an ESTC standard[2] and is subject to independent audit.

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[1] EC Directive 89/391/EEC, Official Journal of the European Communities, 29 June 1989

[2] ESTC Leaflet No 22. Procedures for Licensing MOD Explosives Facilities, March 1994.

9. MOD(UK) explosives licences are issued with three specific objectives in mind:

- The protection of MOD personnel, Service and civilian, and the general public

- The cost effective protection of materiel

- The maintenance of operational readiness standards.

In order that these objectives can be met, the explosives and ammunition concerned must be designed, manufactured and packaged to an acceptable standard, properly classified on the basis of the potential hazard presented, and stored in buildings constructed and operated to recognised standards and managed by competent staff. Given that all of these controls are in place, failure to meet specified Q-D standards will not in itself necessarily preclude the issue of a licence. In such cases, the Chief Inspector should arrange for an assessment to be made of the additional risks generated by the non-compliant situation before deciding how best to proceed.

10. Where the deviation from Q-D standards is small and the additional risks are minor, this assessment can be straightforward and qualitative. For greater risks, more formal risk assessment procedures are required. The QRA method developed by the ESTC is intended to provide a tool to facilitate this formal assessment. The risks associated with the actual, non-compliant situation are assessed and compared with the range of risks given by situations which comply with the Q-D standards. These latter standards have been recognised over many years to provide an acceptable degree of protection and recent work has shown them to involve risk levels which are tolerable[3]. The risks associated with them therefore provide a baseline against which the significance of deviations from the standards can be assessed. Using QRA in this way has the added advantage that many of the uncertainties and inaccuracies in the process are minimised by the comparison.

THE ESTC QRA METHOD

11. The ESTC QRA method is intended to provide an estimate of the upper bound of the risk of fatality to a specified individual or to groups of individuals from the handling and storing of explosives. In both cases, that risk is the product of two components:

- the maximum expected frequency of initiation

- the expected lethality consequent on the maximum credible event.

The successful operation of the method requires the user to define details of the potential explosion site including position coordinates; store size, shape and construction; store contents in terms of net explosive quantity and weapon type and other relevant information and to specify population densities around the site for both workers and the general public. Outputs are calculated in terms of the risks to individuals and societal risk. An overview of the system is given in Figure 1.

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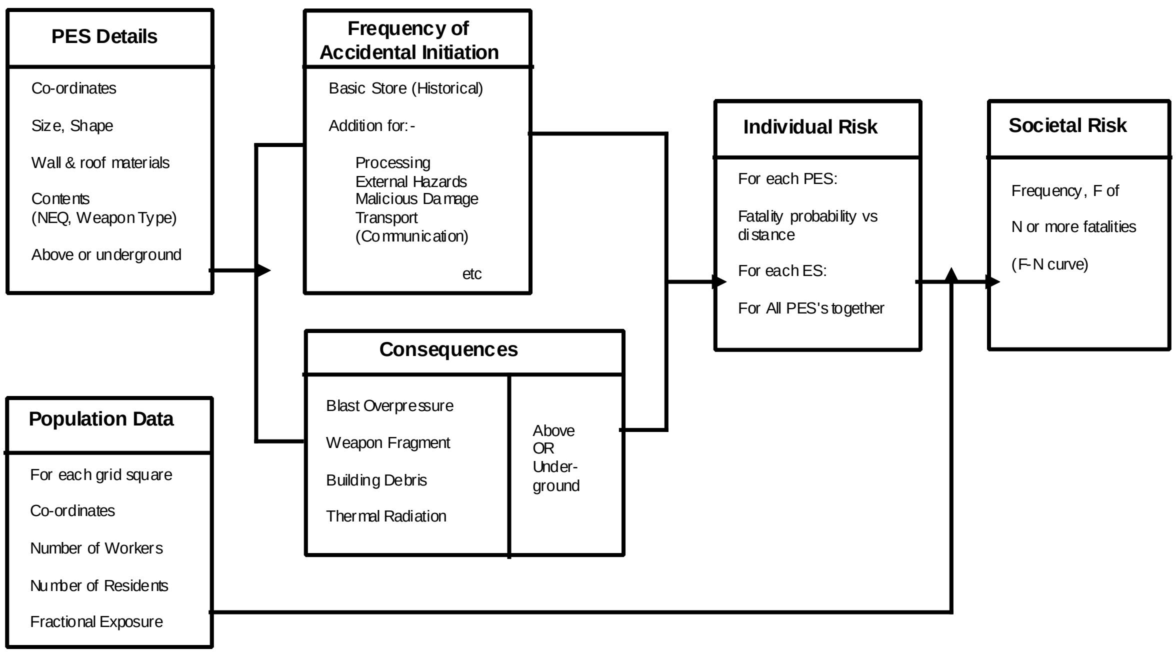
[3] Risk Management of Explosives Storage; D J Hewkin, V J Gill, Sqn Ldr G B Jones, I Self and R A Drake, Proc US DoD Explosives Safety Seminar, Aug 1994.

Figure 1

MOD(UK) EXPLOSIVES RISK MANAGEMENT

AN OVERVIEW



FREQUENCY OF ACCIDENTAL INITIATION

12. Frequencies may be generated by two methods:

- Historical data supplemented by independent expert opinion
- Detailed failure mode analysis.

The former provides a table of basic frequency data for a range of generic classes of explosive and weapon natures. This basic frequency may then be adjusted to take account of other risk factors such as lightning strikes; aircraft crashes; other nearby hazardous installations, including communication from other explosion sites; and malicious damage. The second method generates fault trees but this requires hard data on failure modes. These data are sparse, due in part of the high reliability designed into explosives articles and the very low frequency of accidents. The ESTC has found to date little or no advantage in terms of precision in using this method and it is not expected to be used in the future except in special and limited circumstances.

CONSEQUENCE MODELS

13. Once the total initiation frequency is known for each potential explosion site, the next step is to determine the probability of fatality at each exposed site, given an event at each of the explosion sites. The software includes separate consequence models for assessing lethality from blast, weapon fragments, building debris and thermal radiation. For Hazard Divisions 1.1 and 1.2 all of these models except thermal radiation are combined. For Hazard Division 1.3 only the thermal radiation model is used. There are, world wide, a number of consequence models which might be adopted to meet all or part of the requirement. However, models are only as good as the data on which they are founded and the intelligent use of a model requires some knowledge of those data. The ESTC QRA method employs only models which are believed to be physically sound and for which some assessment of supporting data is possible.

14. Weapon fragmentation data are computed by assigning ammunition to one of six generic types ranging from a 30 mm HE round to a 1000 lb bomb. The type selected is chosen to ensure a worst case estimate. Fatalities from blast are determined by a model developed by David Hewkin, details of which were published in the proceedings of the 1992 DoD Explosives Safety Board Seminar[4]. Other building debris and thermal radiation models are derived from experimental and historical data. Annex B lists the consequence models currently regarded as being sufficiently robust to be employed in the ESTC QRA method.

15. Clearly, this list of models is not comprehensive. For example, the model for building debris relates to brick walled constructions with reinforced concrete roofs. Results for this type of building are available from trials performed in Australia and are often used to represent a worst case. However, hardened aircraft shelters and igloos represent the main MODUK explosives storage situations for which this model is not always appropriate. In these cases agreed data from Anglo/US/Australia trials can be used to generate a worst case envelope which can be applied manually to generate an appropriate output. This means of dealing with debris from these types of structure is seen as a weak link in the method and additional data from current test programmes is urgently required.

16. Another area of weakness is the lack of techniques for assessment of risks arising from transport, not least the loading and unloading of ships. A literature survey and analysis was conducted in the UK in 1992 with the aim of examining in risk terms the significance of ship break up in explosives incidents in ports. An assessment of the final report[5] concluded that the quality and quantity of the data available did not allow the development of a quantitative explosion effects consequence models. This is increasingly seen as an important constraint given the emphasis now placed on rapid deployment and the implications that could have for the transport of explosives through commercial ports.

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[4] Consequences of Pressure Blast : The Probability of Fatality inside Buildings, D Hewkin, Proceedings DoD EST Seminar, Vol 2, 143, 1992.

[5] Frazer-Nash Consultancy Ltd. Report on Ship Explosions, FNC 5055/5918TN, 1992

17. Although it is clear that work is needed to extend and improve the available consequence models, it should also be recognised that the limitations that result from the present inadequacies apply to both Q-D and QRA based controls. Generally, the price which must be paid for inadequate consequence models is an overly conservative control regime.

CONSTRAINTS

18. A number of constraints on the applicability of the QRA method have to be recognised before it can be used. Results are sensitive to several factors including the quality of the site management and of the explosives themselves and the facilities in which they are housed. The method is valid only for sites which are well managed, staffed by competent and experienced personnel and which are subject to regular external inspection to maintain standards. The adoption of QRA does not mean that normal safety requirements can be relaxed. Rather, the method underlines the need for these requirements to be maintained. Similarly, the method as developed applies only to stores which meet the normal requirements for safety and suitability for service, which are properly classified and packaged and which are housed in properly constructed and maintained store-houses. Any deviation from these conditions might cast doubt on the reliability of the assessment.

19. It is also important that the assessment is carried out by staff with experience of both the method itself and the operation of explosives storage sites. Manipulation of the input data and of the frequency and consequence models requires expert knowledge and understanding to ensure consistent application. The overall ESTC QRA model is not sufficiently mature to be handed over for use as a general management tool. Indeed, given the specialised nature of the work and the need for expert interpretation of its outputs, it may never achieve that status. The ESTC Support Group currently maintains a small team to carry out QRA studies, drawing on staff from the Services with their specialised knowledge to support the effort.

20. Finally, it must be recognised that any change in site functions, in management standards or in any of the underlying assumptions behind an assessment must cause that assessment to be reviewed. Risk assessment is not a once and for all procedure and assessments should be continually reviewed to ensure continuing validity. The process is labour intensive and expensive. Risk assessment is not a quick fix or any easy option to get round difficult problems.

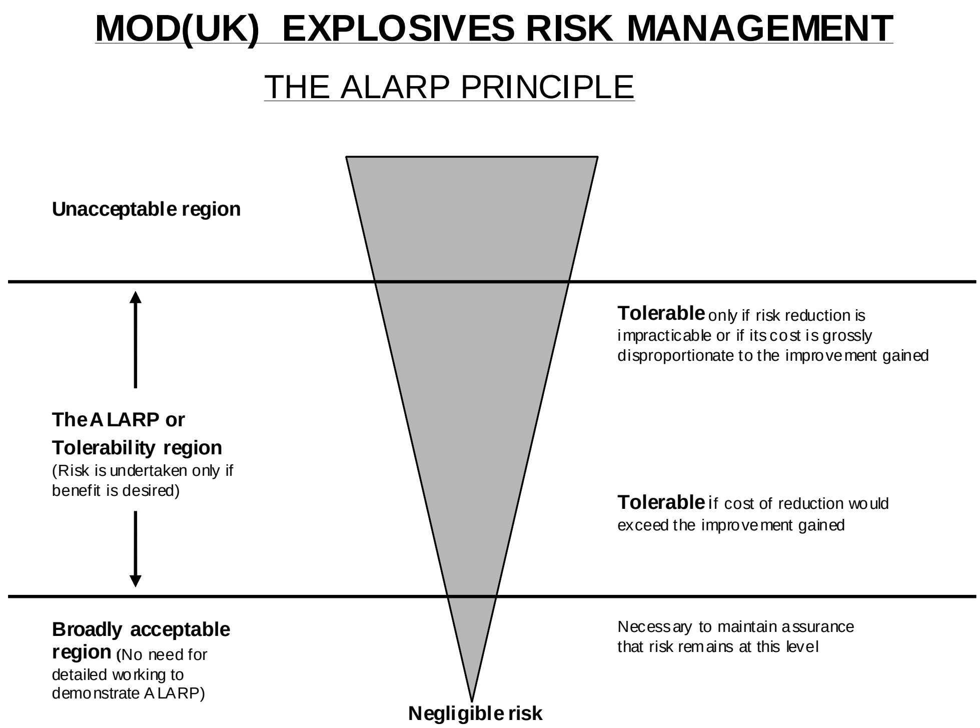
RISKS FROM MOD(UK) SITES

21. The ESTC QRA model was developed with the oversight of a Steering Committee drawn from MOD and other interested Government Departments and of an Independent Advisory Panel. In 1994 the Advisory Panel reported to Ministers that the method developed was broadly in line with developments in generally related fields in industry as a whole. The Steering Committee finished its work at the end of the main development phase and oversight of further improvement was passed to the ESTC.

22. The first stage of this process has involved the application of the method to most of MOD(UK)'s larger explosive storage facilities. A total of 17 sites has now been assessed, including some smaller and more specialised facilities. Details of results obtained at ten of the larger sites have

been published[3]. Nine of these sites met ESTC quantity/distance requirements and, for these sites, the maximum risk of fatality to an individual member of the public fell in the range 3.9×10^{-5} to 1×10^{-7} per year. More recent work confirms this picture with risks to the most exposed members of the public of the order of 1×10^{-5} per year or less. The question must then arise as to whether risks of this size can be tolerated. Within the UK, the Health and Safety Executive (HSE) has taken a lead in addressing the difficult question of the tolerability of risk, and has developed a conceptual framework within which the issue can be discussed, Figure 2.

Figure 2



TOLERABILITY OF RISKS

23. This conceptual framework draws heavily on the statutory requirement to demonstrate that risks are as low as is reasonably practicable - the so-called ALARP principle. It is based on individual risk but the principles apply equally to societal risk. Risks above a certain level are judged to be intolerable and require immediate action to reduce them irrespective of cost. At a substantially lower level is a region where risks are broadly tolerable; this is a region where, provided there is a benefit to be gained and proper precautions are taken the risk does not cause us to alter our normal behaviour. Between these two levels is the important ALARP region.

24. The framework of Figure 2 is expressed in terms of individual risk. It applies equally to societal risk, the risk of widespread or large scale detriment from the realisation of a specified hazard. This is an important but problematical concept. Some commentators argue that a single event leading to multiple fatalities is less tolerable than a large number of lesser events with the same overall lethality. They claim an aversion to such high consequence events. Supporting this, one

might note the public concern following a major air crash and contrast it with the widespread indifference to road accidents. On the other hand, is it really justifiable for risk managers to concentrate on preventing low frequency, high consequence events with the implication that it is worth spending more per life saved to prevent multiple fatalities than it is to prevent single fatalities?

25. Societal risk is often presented in the form of a curve showing the annual probability of a specified event causing N or more fatalities, the FN curve. The area under the FN curve is approximately equivalent to the societal risk in terms of annual expected average harm. As for individual risk, we can identify a region where, for any value of N, the risk is too high to be tolerated and another where the risk is so low as to be negligible. The shapes of the curves defining these regions will depend on the view taken of aversion and on other, site specific, factors. Between these areas lies the ALARP region.

26. In the ALARP region risks must be reduced, as the law demands, so far as is reasonably practicable. The test of reasonable practicability is that the costs of extra safety should not be grossly disproportionate to the benefits accrued. A cost-benefit analysis is essential. The framework of Figure 2 was derived in the light of UK legislation but it has a broader applicability in that it provides a model within which managers can use QRA to assist them in decisions about the cost effectiveness of resource commitments.

27. Determining criteria against which the tolerability of risks can be assessed is difficult. However, the HSE has given some guidance on this. The levels are set not by some absolute scientific law but by what society will tolerate at any given time. Almost certainly this degree of tolerance has reduced over the years, people expect life to become safer and expect to die naturally rather than by accident. On the other hand, in time of war greater risks would be expected and accepted and at any time we might expect those likely to benefit the most to tolerate the greater risk. In the UK no employment involving any significant number of people is estimated to present an individual with more than a 1 in 10^3 chance of death in one year. This level is often quoted as defining the limit of tolerability. At the other end of the scale, figures of the order of 1 death in 10^6 years are regarded as falling at or close to the limit where the risk might be regarded as being negligible.

28. It would be quite wrong to regard these values as set in tablets of stone. Society's expectations will undoubtedly increase, they may vary from place to place and, of course, they may well be influenced by the size of the tax bill! Different activities give different benefits and, in societal risk terms, those most exposed to risk may take a different view from those who benefit at little risk to themselves. Ultimately, decisions on the tolerability of risk are political rather than technical but we might reasonably expect the reduction in world tensions over the past years to be reflected in reduced tolerability of risks associated with defence activity.

Whether that means that the public would expect a lower risk from such activity than from, say, nuclear power plant or chemical plant is another matter.

29. Within the UK, we have been storing military explosives according to ESTC developed quantity/distance criteria for many years without problems. We believe that sites operated in this way generate risks which are tolerable but which require continued attention to ensure they are

maintained at a level as low as is reasonably practicable. If this were not the case, MODUK would not have invested so heavily in licensing, operator training, inspection and all the other activities designed to prevent accidental explosions. It is therefore gratifying to see this view confirmed by the QRA studies conducted to date which, it must be remembered, give an upper bound to the risk presented by MOD licensed sites.

30. Despite this, MODUK continues to avoid setting tolerability criteria. Such criteria, which must take into account public expectation as well as technical matters, can only be derived from political debate and such debate still has a long way to run. Further, the values we derive are upper limits, based on particular assumptions. They cannot necessarily be compared directly with risk estimates for other activities. However that is not to say that QRA has no immediate or practical applications to explosives safety.

APPLICATION OF QRA TO MOD(UK) SITES

31. In general, these applications fall into three categories. QRA helps to deal with unusual or exceptional circumstances outside the scope of standard ESTC guidelines; it provides a management tool to help us set up priorities for action to further enhance the safety of our explosives operations, and, finally, it allows a demonstration of compliance with risk assessment based law.

32. As already noted, before issuing a licence for a MOD(UK) explosives facility, the Chief Inspector of Explosives must be satisfied that, in his professional judgement, the establishment when operating within the terms of the licence will generate risks which are both tolerable and as low as is reasonably practicable (ALARP). Analysis of the application of the QRA method to MODUK explosives sites indicates that tolerability can be assumed to be achieved if Q-D standards promulgated by the ESTC are met and, given that proper management procedures are in place, application of the ALARP principle should not lead to any requirements for significant expenditure to further reduce risks.

33. The expectation is therefore that the majority of MOD(UK) explosives storage sites will be licensed according to standard Q-D rules. Given the supporting QRA work, it can be assumed that sites licensed in this way fully meet statutory obligations provided they are properly managed. The special skills required to carry out QRA analysis are not required of the licensing staff but QRA underpins the Q-D based licence. Q-D and QRA are not alternatives, they are complementary.

34. If the site is operating outside ESTC standards, the Chief Inspector needs to consider the implications of this deviation in terms of additional risk. Often a technical or qualitative assessment will be enough to confirm that the additional risks are minor and that a licence may be issued. On occasions, however, the Chief Inspector may require that a QRA is completed. Where such an assessment indicates that the risk, although increased, remains tolerable then, subject to the application of the ALARP principle, a licence may be issued. Given the deliberate policy of MOD not to set absolute criteria for tolerability, the Chief Inspector's decision on this matter should be based on relative risk, comparing the proposed operation with the situation which might apply if ESTC standards were met or, if that is not possible, with other, similar activities and with the general level of risks posed by MODUK's explosives handling. As a rule of thumb, any activity which posed a risk to an individual more than one order of magnitude greater than the norm based on the ESTC

QRA method would require very careful consideration and it would be very difficult indeed to justify any activity which posed a risk two orders of magnitude greater than that norm.

35. In the rare cases where a Chief Inspector feels he cannot issue a licence, his higher command chain may authorise him to do so, provided the risk affects only MOD personnel or contractors and others working within the MOD owned and controlled site, and provided that the defence need justifies the additional risk. In every case where the assessed risk to the general public is an obstacle to issuing a licence, Ministers must be consulted. Underlying these procedures is the principle that authorisation of the issue of a licence implies acceptance of the risks placed on employees and the general public by the individual giving the authority.

36. The second, and extremely valuable, role of QRA is as a management tool. There is a continuous public pressure to see risks reduced, a pressure which is reflected and politically endorsed in the ALARP principle, but resources are finite. QRA provides a tool for setting priorities to ensure that the limited resources available are used to best effects. It allows a direct comparison of the overall risks of different establishments and, within a site, it allows the major contributors to the risk to be identified and the effectiveness of proposed risk reduction measures to be assessed.

37. Finally, and perhaps obviously, where health and safety law is based on risk management principles, QRA provides a clear indicator of compliance with the law. It is, or should be, a transparent procedure, capable of informing public debate and allowing interested parties to agree on at least one side of the risk/benefit equation. Risk assessment and communication of information on risk to the general public is an important facet of current moves towards more open government, which is necessarily bringing expert judgements into an arena where they can be subject to public scrutiny.

FUTURE DEVELOPMENT

38. When work on the ESTC QRA method began in 1983, it was acknowledged that it would take two decades or more before the system reached full maturity. This view recognised both the technical and political progress which would be required to place QRA on the same footing as quantity/distance based guidance. There is no reason today to question the accuracy of that original forecast.

39. Politically, progress has been made and risk management is increasingly seen in the UK as a useful approach to the statutory control of health and safety at work. Risk management places the ownership and control of risk firmly where it belongs, on the risk generator. Further, risk management based legislation is seen as preferable to prescriptive legislation, as a means of reducing non essential regulatory controls. A review has begun of the Explosives Acts of 1875 and 1923. This review will bring the control of the larger explosives storage sites into line with that of other sites such as chemical plants which present a major hazard to the workforce and the surrounding population. It seems certain that the new Regulations which result will be goal based, requiring the risk generator to provide adequate controls to ensure public safety. Risk assessment will be an essential part of this process.

40. However, there is still some way to go before we have any good understanding of the public

perception of risk or any way of persuading those at risk that they should accept the situation because of perceived benefits to others. Related to this is the difficulty surrounding absolute tolerability limits. This remains a political rather than a technical issue and progress will inevitably be slow while QRA techniques are immature.

41. Technically, and confining our attention to explosives safety, it is unlikely that the first part of the QRA, the estimation of initiation frequencies, can be radically improved. This depends, among other things, on accidents and these, we hope, are few and far between. Therefore, the frequency part of the ESTC QRA method is unlikely to change substantially in the foreseeable future.

42. Consequence models present a different picture. Here there is a substantial amount of work underway. Within the UK, ESTC is working with the HSE to identify models which can be demonstrated to be technically sound. NATO nations, and Australia, are also involved in complementary activities and trials work to provide data against which models can be assessed is underway. Within NATO, work on an explosives safety risk assessment manual is also ongoing.

43. The ESTC QRA method as currently structured is, strictly speaking, limited in scope to explosives storage sites, with a capability to assess processing and on-site storage risks. Work is now beginning to extend that scope to include transport hazards more generally and to provide techniques for assessing ports and dockyards. These areas are well suited to international collaboration and the ESTC would be happy to be involved in such activity.

CONCLUSIONS

44. QRA is now available as a proven and useful technique for the management of risks associated with the storage of explosives. As a method, it places ownership and control of the risk on the risk generator, requiring him to justify continuing to maintain the risk at present levels or to invest resources to reduce it. However, the method itself is expensive to apply; it requires experts to handle the data input and processing and to interpret the output. Further, criteria against which to judge those outputs are politically sensitive. Decision makers need to be aware of the limitations of the method and the uncertainties inherent in risk assessment.

45. It is therefore the view of the MODUK ESTC that Q-D standards should remain the basis for ensuring the safety of explosives storage and transport operations, QRA should be used to underpin those standards, demonstrating compliance with risk based legislation, and to deal with unusual or exceptional circumstances. Investment in developing QRA techniques is, in our view, essential but it is not an easy option.

ANNEX A

GLOSSARY OF TERMS

Hazard	-	The disposition of a thing, a condition or a situation to produce injury. A hazard can simply be regarded as something with the potential to cause harm.
Risk	-	The likelihood that the harm from a particular hazard is realised; the chance of something adverse happening. The idea includes both the probability of something harmful occurring and the consequences of that occurrence.
Individual risk	-	The risk of some specified event or agent harming a statistical or hypothetical person assumed to have representative characteristics. This does not necessarily assume an 'average person'. It may be the person most exposed.
Societal risk	-	The risk of widespread or large scale detriment from the realisation of a specified hazard. Societal risk is often presented in terms of the probability per year of a specified event causing N or more fatalities (fN curve).
Risk assessment	-	An estimation of the risks arising from all identified hazards with a view to their control, avoidance or to a comparison of risks.
Quantified Risk Assessment (QRA)	-	A risk assessment incorporating numerical estimates.
Tolerable	-	The range of risk levels which is deliberately run on a regular basis for a benefit. A range which is not regarded as negligible or something which might be ignored but rather as something to be kept under review and reduced further if and so it is possible to do so.
Risk management	-	The application of a set of measures relevant to a particular set of significant risks and intended to restrict and maintain risks within tolerable limits at proportionate costs.
Risk control	-	The overall activity of identifying and limiting or managing risks. The term includes a concept of achieving evenness in the distribution of risk and of proportionality to risk in allocating expenditure.
Maximum credible event (MCE)	-	The worst single event likely to occur from the accidental explosion of a given disposition and quantity of ammunition and explosives. The event must be realistic with a reasonable probability of occurrence. The MCE may be used as a basis for effects calculations.

CONSEQUENCE MODELS

Above ground	Variables	Reference	Short Name	DRIC Ref
Blast - Indoors	NEQ Distance	RAST 1539	PRES01	BR325887
Blast outdoors	NEQ Distance	RAST 1554 & Hewkin DODESB 1992	PRES01	BR325886
Weapon Fragments	NEQ Distance Weapon Type (Frag density, max velocity, max frag weight) Exposed Site - In/Outside PES - Traversed/Untraversed	RAST 1691	ROFRAP	BR325905
Building Debris ESH	NEQ Distance PES dimension (Length, Width & Height) Wall Thickness.	RAST 1454 (MoD Trials Henderson)	FRAGS01	BR325880
Building Debris Igloo/HAS	NEQ Distance	RAST 1721 (In course of preparation with Distant Runner trial data.)		
Thermal Rad	NEQ Distance	RAST 1543 (Historical MoD results)	TRAD01	BR325889

Below ground				
Blast	NEQ Distance: Angle to Adit Normal Depth of Cover Free Volume	RAST 1692	FATBLAST	BR325906
Weapon Fragment	No significant contribution	RAST 1701	N/A	BR325907
Debris	NEQ Distance Volume of Blown Cover	RAST 1520 (China Lake. Jarret)	UFRAG1	BR325885
Thermal Rad	NEQ Distance Loading density (Blast model) Volume of Chamber Area of exit from chamber	RAST 1577	THERM	BR325894